

# Sonographic visualization and ultrasound-guided blockade of the greater occipital nerve: a comparison of two selective techniques confirmed by anatomical dissection

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**Background.** Local anaesthetic blocks of the greater occipital nerve (GON) are frequently performed in different types of headache, but no selective approaches exist. Our cadaver study compares the sonographic visibility of the nerve and the accuracy and specificity of ultrasound-guided injections at two different sites.

**Methods.** After sonographic measurements in 10 embalmed cadavers, 20 ultrasound-guided injections of the GON were performed with 0.1 ml of dye at the classical site (superior nuchal line) followed by 20 at a newly described site more proximal (C2, superficial to the obliquus capitis inferior muscle). The spread of dye and coloration of nerve were evaluated by dissection.

**Results.** The median sonographic diameter of the GON was  $4.2 \times 1.4$  mm at the classical and  $4.0 \times 1.8$  mm at the new site. The nerves were found at a median depth of 8 and 17.5 mm, respectively. In 16 of 20 in the classical approach and 20 of 20 in the new approach, the nerve was successfully coloured with the dye. This corresponds to a block success rate of 80% (95% confidence interval: 58–93%) vs 100% (95% confidence interval: 86–100%), which is statistically significant (McNemar's test,  $P=0.002$ ).

**Conclusions.** Our findings confirm that the GON can be visualized using ultrasound both at the level of the superior nuchal line and C2. This newly described approach superficial to the obliquus capitis inferior muscle has a higher success rate and should allow a more precise blockade of the nerve.

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Local anaesthetic blocks of the greater occipital nerve (GON) are frequently performed either to diagnose or to treat pain mediated by the GON. According to the classification of the International Headache Society, a positive response to a local anaesthetic block of the GON is necessary to establish the diagnosis of occipital neuralgia.<sup>1</sup> Studies have shown the possible effectiveness of injections of the GON for the treatment of different types of headache.<sup>2,3</sup> Although easily performed, the classical method of injecting 'blindly' just medial to the palpated occipital

artery at the level of the superior nuchal line<sup>4</sup> is not target-specific. Imprecise use of higher volumes could lead to additional blocks of other nerves nearby like the lesser or the third occipital nerve and to i.m. spread with unspecific analgesic effects. A successfully targeted block of the GON with minimum amount of local anaesthetic and confirmed sensory changes in its distribution is necessary to make a specific diagnosis. Until today, no selective approach for the GON is available, and as such, GON blocks have never been performed under controlled conditions.<sup>5</sup>

High-resolution ultrasound has the potential to visualize small peripheral nerves and to facilitate real-time local anaesthetic blocks with high precision.<sup>6,7</sup> Therefore, we evaluated whether sonographic visualization of the GON was possible at the classical block site and compared this with a newly developed approach further proximal. Subsequently, the accuracy of ultrasound-guided injections of the GON using a low volume (0.1 ml) of dye at both sites was studied in an established cadaver model by anatomical dissection.<sup>7</sup>

## Methods

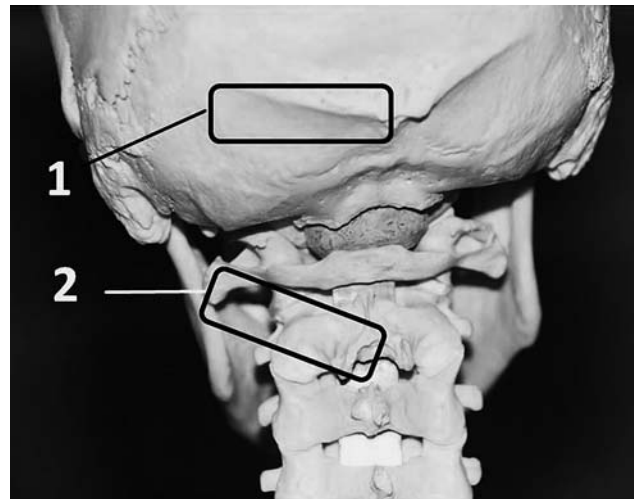
### *Cadaver model*

After obtaining institutional approval for the usage of cadavers that were in the legal custody of the Department of Anatomy, Histology and Embryology of the Innsbruck Medical University, Innsbruck, Austria, the study was carried out on 10 embalmed corpses. The embalming fluid consisted of ethanol 96% with glycerol 85% (0.3 litre for every 10 litre of ethanol) and phenol 90% (up to 0.1 litre for every 10 litre of ethanol). As previously described,<sup>7</sup> the embalming process cannot stop postmortem gas formation in tissue, which when present severely restricts ultrasound visibility. Accordingly, the ventral cervical region of all cadavers were pre-scanned by an independent examiner (B.M.) using the same ultrasound machine used for the study (Sonoline VersaPlus with a 7.5 MHz linear array transducer 7.5L70; Siemens Medical Solutions, Erlangen, Germany). All 10 cadavers provided good image quality without gas artifacts and were included in the study.

The cadavers were placed in a prone position with the head and neck flexed to compensate for cervical lordosis. All subsequent sonographic measurements and ultrasound-guided interventions were performed by two anaesthesiologists with experience in ultrasound-guided regional anaesthesia and pain management (U.E. and M.G.). Sonographic images were recorded digitally on the hard disk of the ultrasound system.

### *Ultrasound-guided classical distal block technique*

The ultrasound probe was initially placed in a transverse plane over the classical block site, at the level of the superior nuchal line, with the centre of the probe ~2–3 cm lateral to the external occipital protuberance (Fig. 1). In the cadavers, no shaving was necessary. The GON was identified in the short axis plane,<sup>8</sup> and its size, depth, and distance from the midline were recorded. Then, under real-time scanning, a 21 G, 5 cm, short bevelled needle was guided with ultrasound using an in-plane (IP) technique<sup>8</sup> from lateral to medial to position the tip of the needle exactly at the centre of the nerve. Thereafter, 0.1 ml of

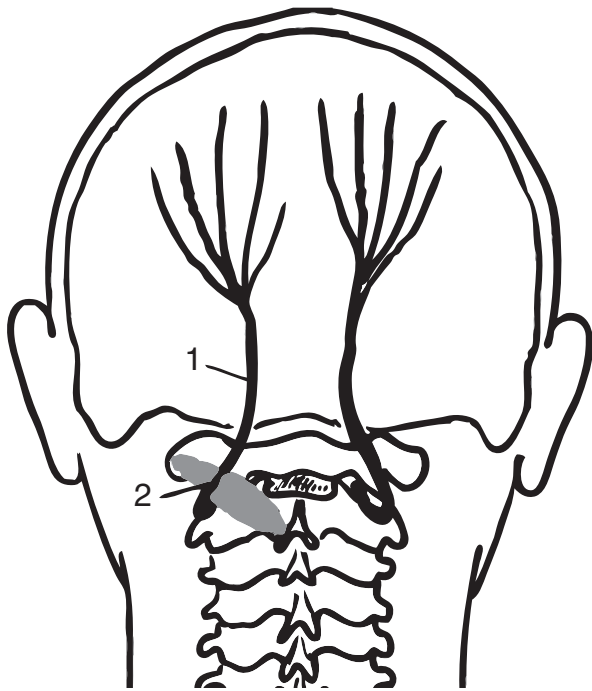


**Fig 1** Transducer positions for ultrasound-guided blocks of the GON. 1, Classic block site at the superior nuchal line; 2, new block site at C2.

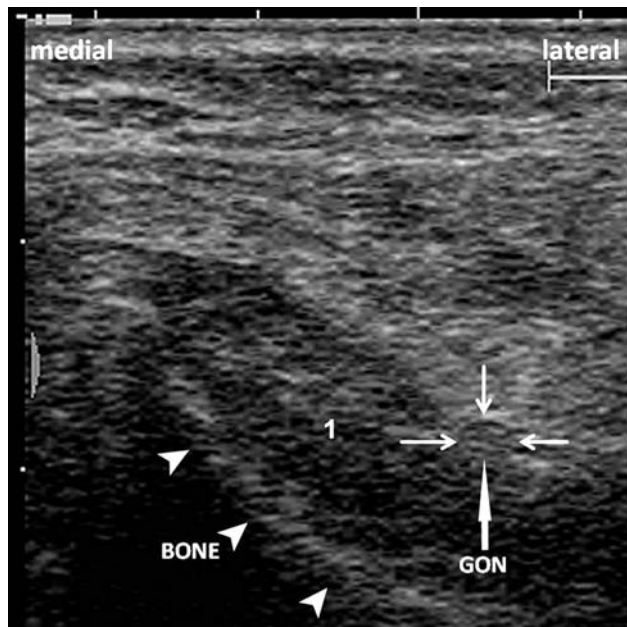
indocyanine green (ICG) (ICG-Pulsion, Pulsion Medical Systems AG, Munich, Germany) was injected under direct visualization. This technique was then repeated on the other side of the cadaver.

### *Ultrasound-guided new proximal block technique*

The ultrasound probe was then moved down the neck, using a transverse midline orientation initially, the external occipital protuberance was identified, and then moving caudally over the atlas, the spinous process of C2 was located. The spinous process of C2 can easily be identified as it is always bifid, showing two tubercles in contrast to the smooth outline of the posterior arch of the atlas. The GON is the posterior ramus of C2, and emerges below the posterior arch of the atlas. It curls around the lower border of the obliquus capitis inferior muscle and passes cranially superficial to this muscle across the roof of the suboccipital triangle (Fig. 2). The relationship of the GON to the obliquus capitis inferior muscle is constant and reliable, and as such, we decided to use this as the primary landmark for the new approach. Once the spinous process of C2 had been identified, the probe was moved laterally identifying the obliquus capitis inferior muscle of the neck. This muscle has its attachments at the bifid spine of the axis (C2) and the back of the transverse process of the atlas (C1); it passes obliquely upwards and outward. To maximize the image of this muscle and the lamina of C2, the probe needs to be rotated slightly (lateral end positioned more cranially than the medial end) to bring it parallel to the long axis of the muscle (Figs 1 and 2). After curling around the caudal edge of the muscle, the GON lies superficial to the obliquus capitis inferior muscle, crossing it from caudal to rostral and lateral to medial, and can be easily visualized at this level with ultrasound (Fig. 3). Measurement of its size, depth, and distance from the spinous process of C2 and third occipital nerve was



**Fig 2** Schematic drawing of the course of the GON. 1, Classic block site medial to the occipital artery at the superior nuchal line; 2, new block site over the obliquus capitis inferior muscle (grey) at C2.



**Fig 3** Ultrasound image obtained by the transducer position 2 in Figure 1. 1, Obliquus capitis inferior muscle; BONE, lamina of C2; GON, greater occipital nerve.

recorded. Similar to the GON and medial to it, the third occipital nerve is also running on top of the obliquus capitis inferior muscle. We measured the distance between them, if both were identifiable. A 21 G, 5 cm, short bevelled needle was then inserted using the IP technique



**Fig 4** The anatomical dissection shows four injection sites. The upper two are at the classical block site at position 1 in Figure 2. The lower two are at the new block site at position 2 in Figure 2. The tips of all four needles are in the GON, and the nerve is coloured by ICG.

beneath the lateral border of the probe and advanced medially till the needle tip was positioned exactly at the centre of the nerve. Then, injection of 0.1 ml of ICG was completed as described above. Finally, the procedure was repeated on the contralateral side.

#### Dissection and evaluation

After completion, all four needles were left in place and each cadaver was carefully dissected with manual fixation of the needles by the independent anatomical specialist (B.M.), who was not involved in ultrasound measurements and block performance. The simulated block was classified as successful, if the ICG coloured the targeted nerve and this nerve was identified as the GON by anatomical dissection (Fig. 4). Differences in success rate between the two approaches were evaluated for significance with McNemar's test using SigmaStat 3.5 for Windows (Systat Software Inc., Point Richmond, CA, USA).  $P < 0.05$  was considered statistically significant.

#### Results

In 10 cadavers, 40 approaches to the GON were performed: 20 at the classical block site and 20 at the site of the new approach, which is more proximal, close to the C2 root, and superficial to the obliquus capitis inferior muscle.

Characteristics of the 10 cadavers were: sex: three males, seven females; median age at death 83 (range 45–96) yr; median height 168 (SD 7.5) cm; and median BMI 17.7 (SD 3.8) kg m<sup>-2</sup>. Results of the ultrasound measurements are shown in Table 1. The GON was successfully coloured in 16 of 20 using the classical approach and in 20 of 20 using the new approach. At the classical block

**Table 1** Ultrasound measurements of the GON in 10 cadavers expressed as median (range) in millimetres. The four measurements without verified correct needle placement by the following anatomical dissection in the classical approach (A) were excluded. TD, transverse diameter; VD, vertical diameter; Depth, distance from the surface to the nerve; NPD, distance from the nerve to the external occipital protuberance/midline; NSD, distance from the nerve to the C2 spinous process/midline; NTD, distance from the GON to the third occipital nerve. \*Measurement was possible in 19 of 20 cases; in one case, the third occipital nerve was not clearly identifiable by ultrasound

Approach	<i>n</i>	TD	VD	Depth	NPD	NSD	NTD
Classic (A)	16/20	4.2 (3.3–6.6)	1.4 (1.0–1.8)	8.0 (5.3–10.9)	17.4 (11.1–22.8)		
New (B)	20/20	4.0 (3.2–5.6)	1.8 (1.2–2.6)	17.5 (9.8–29.0)		27.6 (18.9–32.6)	14.9 (9.0–20.5)*

site, anatomical dissection revealed four misses, where the GON was more medial, 11 entirely coloured single nerves, two partially coloured single nerves, and three cases of multiple branches, where at least one branch was entirely coloured by the dye. At the new block site, anatomical dissection revealed no missed nerves, 18 entirely coloured single nerves, one partially coloured single nerve, and one case of three branches, where two branches were coloured by the dye. Using very low volumes of 0.1 ml, the success rate of a simulated GON block was 80% (95% confidence interval: 58–93%) in the classical and 100% (95% confidence interval: 86–100%) in the new approach ( $P=0.002$ ).

## Discussion

This is the first description of successful sonographic visualization of the GON and comparison of two ultrasound-guided approaches with it. The results of our anatomical dissections indicate that ultrasound guidance has the potential to turn GON blocks into a highly selective and accurate procedure. In contrast to the indirect methods of localization of the GON, which are based on either arterial palpation,<sup>4</sup> the use of a Doppler flow probe,<sup>9</sup> or sensory nerve stimulation,<sup>10</sup> ultrasound allows real-time identification of the nerve and recognition of anatomical variability in its course, division and relationship to surrounding structures. The ability to guide the needle and observe the spread of local anaesthetic with ultrasound can be invaluable to avoid complications as have been described using the indirect method.<sup>11</sup>

Spread of injectate in embalmed cadavers is not the same as in living subjects, but comes very close. Owing to the ‘soft-embalming method’, tissues remain flexible, smooth, and provide a familiar pattern of injectate spread under direct sonographic vision, as we know from previous studies<sup>7</sup> and workshops. To furthermore minimize the difference, very low volumes (0.1 ml) were used in this investigation. If we were able to colour a nerve with such a demanding low volume of dye, a block failure under clinical conditions with higher volumes of local anaesthetics would be very unlikely, even in cases of additional nearby branches.

With a standard linear transducer (7.5 MHz), we were able to correctly localize the GON and perform a successful selective ultrasound-guided intervention in 100% of

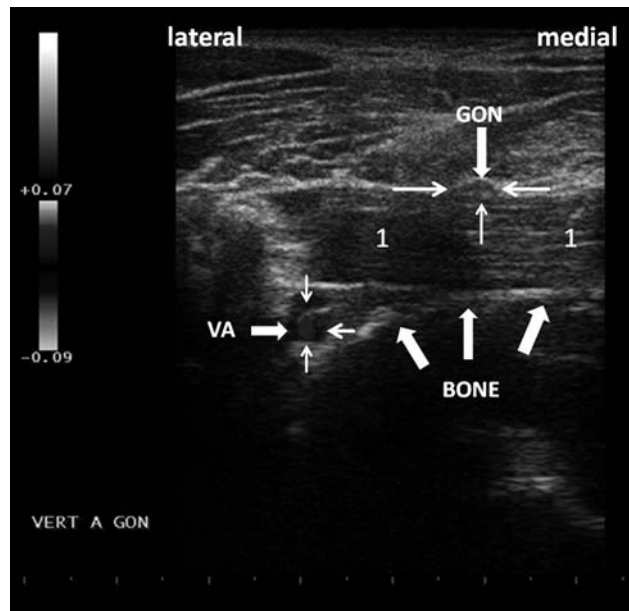
cases with the new approach using the obliquus capitis inferior muscle as the primary landmark. At the classical block site, over the superior nuchal line, the success rate was only 80%. Here, the GON was generally more difficult to visualize due to the ultrasound appearance of the overlying aponeurotic tissue and the short distance between the nerve and the transducer. Even using a higher frequency probe of 10 MHz with improved resolution did not improve the ability to reliably see the nerve at this site, which was most likely due to artifacts from the bone surface and aponeurotic tissue. Theoretically, a 13–15 MHz transducer with a gel pad could provide advantages at the classical site, which we have not verified in cadavers. With this setting, small peripheral branches of the GON may perhaps be visible sonographically. However, in the living, concerns of practicability, sterility, and the removal of hair do not support this option.

The first part of the course of the GON is closely related to the obliquus capitis inferior muscle, which connects the spinous process of C2 with the transverse process of C1. Here, superficial to its landmark muscle, the nerve can easily be visualized with ultrasound. More distally, the GON divides in many branches and courses through the semispinalis capitis muscle finally piercing this and the trapezius muscles’ aponeurosis at variable locations.<sup>12</sup> Interestingly, Loukas and colleagues<sup>13</sup> found a high variability (1.5 to 7.5 cm) of the GON’s distance to the midline at a horizontal level between the external occipital protuberance and the mastoid process in 100 cadavers.

The marked variability and multiple branching of the GON at the classical block site are the reason that relatively high volumes of local anaesthetic are clinically used for ‘blind’ blocks at this location. This often results in non-selective blockade of other nerves, including branches of the lesser and third occipital nerve and also the greater auricular nerve.

The new proximal ultrasound-guided approach has several advantages compared with the classical one. At C2 below the hairline, skin disinfection is easier and shaving is normally not necessary. Here, the nerve is deeper, lying between tissues with distinct sonographic appearances, neither obscured by bony artifacts nor in close proximity to an artery. At this level, if indicated, selective cryoanalgesic techniques could be performed without the potential danger of occipital artery damage. Clinically, more





**Fig 5** Ultrasound image in a living subject according to transducer position 2 in Figure 1. 1, Obliquus capitis inferior muscle; BONE, lamina of C2; GON, greater occipital nerve; VA, vertebral artery with Doppler signal inside.

proximal blockade of the nerve often provides better results compared with distal approaches, especially in occipital neuralgia where nerve entrapment is almost always proximal. Gille and colleagues<sup>14</sup> showed that neurectomy and sectioning of the obliquus capitis inferior muscle at this location was highly successful when performed in selected patients.

This new approach is deeper and more proximal than the classical approach, and caution needs to be taken because the vertebral artery and the spinal cord are in close proximity. The vertebral artery is lateral to the GON deep to the obliquus capitis inferior muscle and the lamina of the atlas, while the spinal cord is medial and again deep to the muscle. Because of that, good needle control and experience in ultrasound-guided interventions are required. The obliquus capitis inferior muscle is ~1 cm thick at this level. Positioning of the probe so that the full thickness of the muscle overlies the bony shadow of the vertebral arch of C2 gives improved safety when performing this technique, eliminating any possibility of inadvertent intravascular injection or the spinal cord puncture. In addition, in the living, the vertebral artery can be seen lateral and deep to the muscle (Fig. 5). However, under no circumstances, should this new approach be performed without direct ultrasound guidance.

Our new methodology offers interesting future perspectives for further research in the field of occipital headache. Today, we know that occipital neuralgia can be a consequence of nerve pathology like schwannomas<sup>15</sup> but also related to other conditions such as giant cell arteritis,<sup>16</sup> hypermobile posterior arch of the atlas,<sup>17</sup> or C1/2 joint

arthritis.<sup>18</sup> With this new method, diagnostic nerve blocks can be even more selective than before. This could enhance our knowledge about occipital neuralgia in the clinical context and help to establish a diagnosis before invasive treatments are considered.<sup>19–22</sup>

Interestingly, effects of occipital nerve blocks in cluster type headache,<sup>23 24</sup> migraine,<sup>25 26</sup> cervicogenic headache,<sup>27</sup> and postdural puncture headache<sup>10</sup> have recently been described. Selective GON blocks may help further to clarify this relationship and the relevance of functional connectivity of occipital and trigeminal nerves.<sup>24</sup>

In conclusion, and with the knowledge that these results were achieved in relatively old and low weight cadavers only, this study suggests that ultrasound guidance facilitates highly selective GON blocks. The GON could consistently be visualized sonographically at the newly developed proximal approach at C2, where it lies superficial to the obliquus capitis inferior muscle. Using ultrasound, the new site has a simulated 100% block success rate with the application of only 0.1 ml of dye, confirming that a precise, reliable blockade of the GON can be achieved using ultrasound. Although in this cadaveric study, the new approach proved significantly superior to the classic approach, this will need to be supported by future clinical studies.

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## Conflict of interest

None declared.

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